Communication by Whispers Paradigm for Short Range Communication in Cognitive Radio Networks using Interference Based MAC Sensing for Opportunity Discovery

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***Abstract*— With ever increasing demand for efficiency and increased throughput over the wireless domain, we have now reached a point where in a method for efficient utilization of the electromagnetic spectrum is in demand. Cognitive radio provides us with a way in which this demand could be catered, it does so by using devices which autonomously adjust their communication parameters to adapt to the external environment. However, the most critical of this entire technology is the parameter relating to the Spectrum Sensing aspects. In order for cognitive radio devices to properly configure and identify the presence of a primary carrier in a communication mode, spectrum sensors and efficient sensing algorithms are required. There have been many algo- rithms developed in this field. However, these available spectrum sensing algorithms are prohibitively expensive to implement in wireless devices that cater to only short distance communication. In this paper, we propose a parsimonious spectrum sensing algorithm which would deal with sensing and couple them with short distance wireless devices over WiFi networks operating in the 2.4 GHz band. The efficiency parameters are also shown using demonstrations.**

***Index Terms*— Cognitive Radio, Spectrum Sensing, Wireless, Short-Range Communications**

I. Introduction

The concept of a cognitive radio was envisioned by Joseph Mitola III in his Ph. D. dissertation [1]. It's a paradigm for wire- less communication in which node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users. Currently, there are two tiers of cognitive radios: the Full Cognitive Radio, also known as the Mitola Radio, which is depicted in details by Stevenson et al in [2] and the other is the Spectrum Sensing Cognitive Radio (SSCR) which is given in greater detail in [2]. Most realizations of cognitive radios are concentrating in the implementation of the SSCR aspect of CR with spectrum sensing, allocation, modulation schemes, etc. as their area. This paper will also concentrate on the SSCR tier of CRs but, in addition we will be providing a viable, parsimonious spectrum sensing, algorithm for short distance communications. We feel that through short distance communications CRs could be of immense use, moreso because they communicate with a lesser power and energy as opposed to the long distance ones.

II. Related Work

There has been a number of protocol standards that have been proposed earlier in the spectrum sensing domain of CR. The prior works have concentrated on several physical layer techniques like energy detection as in [3], matched filter [4], future detection as in [7], etc. However, there has been limited number of publications on the MAC-layer sensing methods. The recently published methods have been from Chou in [4] concentrating on sensing using pre-determined periods, then by Zhao et al in [5] and Sankaranarayan et al in [6] have concentrated in using CSMA based slotting mechanisms. All of these methods have aimed at providing solutions for the general distance CRs, but, these methods would add to immense overheads when we are concentrating only on a short-range communications in the order of several meters of radii. We suggest one simple alternative to reducing such over heads of a short range CR Network by using the concept of Interference Temperature sensing using Interference Temperature Models (ITM). Kolodzy in [7] and Clancy et al in [8] first proposed this model and more recently Tandra et al in [9], Cabric et al in [10] and Sharma et al in [11] have all used ITM as their base in devising methods for spectrum sensing, but, again all of them seem to be concentrating on the wider aspects of CR. We segregate the short-distance communication as a different category of problems and propose interference based sensing algorithm which is along the lines of using the combination of MAC layer sensing, ITM and our own strategies to scale down the power. We term this paradigm as "Communications by Whisper", whose main aim is to leverage the CR concept for effective short range communications. We also come up with simulation results demonstrating the efficacy of the proposed sensing scheme, as well as its performance improvements

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over the previously proposed schemes in the short range arena.

III. Interference Temperature Model

The concept of interference temperature is identical to that of noise temperature and was first proposed by Kolodzy and Clancy et al in [7] and [8] respectively. It is a measure of the power and bandwidth occupied by interference. Kolodzy et al in their paper described Interference temperature T_I, specified in Kelvin and as

$$T_I(f_c, B) = \frac{P_I(f_c, B)}{kB}$$

Where $P_I(f_c, B)$ is the average interference power in Watts centered at f_c, covering bandwidth measured in Hertz. Boltzmann's constant k is 1.38 x 10^{23} per Kelvin degree. The idea that was behind this model is that by taking a single measurement, a cognitive radio can completely characterize both interference and noise with a single number, even-though, the interference and noise behave differently.

Thus when applied over a range of B, the equation could be represented as follows

$$T_I(f_c, B) = \frac{1}{Bk} P_I(f_c, B)$$

$$= \frac{1}{Bk}\left(\frac{1}{B}\int_{f_c-B/2}^{f_c+B/2} S(f)df\right) = \frac{1}{B^2k}\left(\int_{f_c-B/2}^{f_c+B/2} S(f)df\right)$$

Where, S_f represents power spectral density of our current RF environment. This gives us a way to compute T as a function of B.

IV. Implementation of the Model

In implementation we mainly deal with the way in which, for a given geographic area, we could tweak the interference temperature model to accommodate an Interference Temperature limit, T_l. This value would be a maximum amount of tolerable interference for a given frequency band in a particular location (.i.e any unlicensed transmitter utilizing this band must guarantee that their transmissions added to the existing interference must not exceed T_l). The following section will explain the way in which this tweaking is done.

A. *Interference Temperature Measurement*

In this section we describe a measurement technique called interference temperature measurement (ITMes) (Paul J Kolodzy [7]). ITMes relies on the CRs ability to sense its environment and regulate bandwidth and power usage on a per-packet basis. It uses IT to sense its environment, and transmits using the power levels that are determined using the *anticipatory detection* technique, which is explained in the next section.

We use the work of Kolodzy as our premise and use the observations and formulations in our model to calculate the Interference Temperature. The formulae that were given by Kolodzy are:

$$S = \frac{E^2}{377\Omega} \quad \text{and} \quad IT = \frac{S}{k}$$

Where, k is Boltzmann constant.

Algorithm

In our Medium Access Control, each node runs a RTS packet test to calculate its transmission power as shown in **Algorithm 1** *StoreDSlog()*. The test bed is arranged in such a way that on every run, each node needs to negotiate with each other about the transmission power they are adopting. During negotiation phase, each node broadcast a *strategy* packet to its neighbors. The *strategy* packet that we have designed is a RTS-like packet that has a provision for the receiver to reply to the sender with a local SINR and the timestamp. Each sender node then calculates the SINR based on the information from the strategy packet, and stores the related SINR information of send. During the data transmission phase, each node looks through its database to find the related SINR information for the receiver. The database of the entire process is centralized and store as a *delimiter separated log (DSLog)*(as shown in *updateDSLog()*). Over a period of time, when more and more data about the SINR accumulates in the DSLog, we could now use and interpret the pattern of the DSLog

```
//i.updateDSLog() - for i^th node to update the DSLog
with concurrency
while true do
    bufferTheUpdate();
    for k = 1 to n-1 do
    { flag(i)← k;
    turn(k) ← i;
    waitfor{∀j ≠ i : flag(j) < k}OR{turn(k) ≠ i}
    } flag(i)← 0;
    remainder_section();
end
//isTransmittable() to determine possiblity of
transmission
while true do
    current =
    runDataSearchAll(DSLog, i, curr_time)
    //returns the list of lines from DSLog that
    corresponds to 5minutes niegbourhood of curr_time
    pattern = max(correlation(current, DSLog, i))
    //returns that segment in DSLog that has a max
    correlation value greater than 0.5
    while changeFlag ≠ 1 do
        poll(DSLog)
        trasmit(i)
        //transmit the packets to i
    end
end
//Pseudocode for StoreDSLog()
init();
while true do
    mySINR[myNode] ← calcLocalSINR();
    //calculate and store i^th SINR in mySINR[i]
    store(time, mySINR, myNode);
end
```

Algorithm 1: Pseudocode of the Proposed Technique

variations using *regression techniques* that are available with log analytics tools(as shown in *isTransmittable()*).

IV. Simulation and Results

In order to verify our model an application was designed and implemented using a combination of Perl, NetworkSimulator-2, WEKA analytics tool and Java development platform. For this, we compared the working of the Synchronized Medium Access Control (SMAC)[12] and our Interference Based MAC over ten nodes, using random topology and AODV routing protocol. The tests are explained below

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Test #1: Throughput in Homogeneous Topology

The aim of this test was to estimate and compare the throughput of the interference based MAC along with the traditional MAC protocol. The test was conducted under identical topology and routing protocol. However, the MAC was replaced. The fig 1(a) shows the throughput v/s time plot for the traditional MAC protocol and fig 1(b) shows a similar plot for the proposed MAC protocol. It was observed that the proposed MAC protocol is almost the same, with our proposed MAC have a slight edge of about 3.5% increase in the throughput.

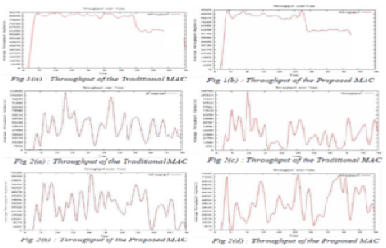

Fig 1(a) : Throughput of the Traditional MAC; Fig 1(b) : Throughput of the Proposed MAC; Fig 2(a) : Throughput of the Traditional MAC; Fig 2(c) : Throughput of the Traditional MAC; Fig 2(b) : Throughput of the Proposed MAC; Fig 2(d) : Throughput of the Proposed MAC

Test #2 : Reaction Time in Heterogeneous Topology

The aim of this test was to estimate and compare the way in which a heterogeneous network of the interference based MAC and the traditional MAC protocol work. The topology consisted of two kinds of nodes, one that has our MAC embedded in it and the other that has the traditional MAC embedded in it. The test was conducted under identical topology and routing protocol. However, the MAC was replaced; half of the nodes were equipped with the traditional MAC and the other half with the proposed MAC protocol. The fig 2(a), 2(b), 2(c) and 2(d) show the throughput v/s time plot for various scenarios. The scenarios in 2(a) and 2(b) the traditional MAC protocol's throughput graph is as shown in 2(a) and that of the proposed MAC is depicted in fig 2(b). We can observe that the throughput of the traditional MAC, on an average is about 40 percent higher than the average value of the shows a similar plot for the proposed MAC protocol. On the other hand, the scenarios in fig 2(c) and fig 2(d) the traditional MAC protocol's throughput graph is as shown in 2(c) and that of the proposed MAC is depicted in fig 2(d). However, the difference between the scenarios in 2(a) and 2(b) is that the scenarios 2(c) and 2(d) we make a slight modification to the previous timing model, so that, the communication amongst the traditional MAC nodes occurs at high data rates till 17 seconds and then it reduces the data rates to half its initial value. Through the graphs we can observe that the throughput of the traditional MAC and the proposed MAC alternate in behavior.

IV. Conclusions

After a series of simulations over the proposed model we could conclude that the amount of resources that the proposed model of collaborating ideas of using Interference Temperature on to the Medium Access Control of the Cognitive Radio systems, has a very significant potential in those scenarios which demand co-existential spectrum sharing behavior amongst nodes which are separated by a short distance. Not only does the simulatory results show that the technique is efficient in terms of increasing the throughput of the cognitive radio environment, but also in terms of efficient co-existence of the proposed MAC nodes with those of the traditional MAC nodes in a heterogeneous environment. We have observed the proposed model leverages a sensing time to less than 0.9 seconds by compensating a loss of 3% on the overall throughput. Apart from this, we have also observed that when the transmission power parametric of the cognitive radio nodes is reduced during a short range communication. This leads us to proceed with the usage of this new paradigm of "Communication by Whispers".

References

[1] J. Mitola III, "Cognitive Radio: An Integrated Agent Architecture for Software Defined Radio", *Doctor of Technology Dissertation,* Royal Institute of Technology (KTH), Sweden, May 2000.

[2] Carl, Stevenson, G. Chouinard, Zhongding Lei, Wendong Hu, S. Shell- hammer and W. Caldwell, "IEEE 802.22: The First Cognitive Radio Wireless Regional Area Networks (WRANs) Standard". *IEEE Commu- nications Magazine* (US: IEEE) 47 (1): 130138

[3] S. Haykin, "Cognitive Radio: brain-empowered wireless communications", *IEEE Journal on Selected Areas in Communications*, Volume 23, no. 2, pp.201-220, 2005.

[4] C.T. Chou, "Adaptive quality-of-service provisioning in wireless/mobile networks", *PhD Thesis*, University of Michigan, 2004.

[5] Q. Zhao, L. Tong and A. Swami, "Decentralized Cognitive MAC for Dynamic Spectrum Access", *IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks*, November 2005.

[6] S. Sankaranarayanan, P. Papadimitratos and A. Mishra, "A bandwidth sharing approach to improve licensed spectrum utilization", *IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks*, November, 2005.

[7] Paul J. Kolodzy, "Interference temperature: a metric for dynamic spectrum utilization", *Wiley International J. Network Management*, vol. 16, pp. 103-113, 2006.

[8] T. Clancy, "Formalizing the Interference Temperature Model", *Wiley Wireless Communications and Mobile Computing*, 2006.

[9] R. Tandra and A. Sahai, "Fundamental limits on detection in low SNR under noise uncertainty", in *Proc. of the WirelessCom 05 Symposium on Signal Processing*, Maui, HI, June 1316 2005.

[10] D. Cabric, A. Tkachenko, and R. W. Brodersen, "Experimental study of spectrum sensing based on energy detection and network cooperation", *iEEE MILCOM*, 2006.

[11] Manuj Sharma, Anirudha Sahoo, and K. D. Nayak, "Channel Selection under Interference Temperature Model in Multi-hop Cognitive Mesh Networks"

[12] Yogesh R Kondareddy and Prathima Agrawal, "Synchronized MAC Protocol for Multi-Hop Cognitive Radio Network", *IEEE International Conference on Communications*, Beijing, China, 2008

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